ment of Agriculture Agricultural Research Service May 1991

Agricultural Research

Relentless marauders? Who, us?

Gypsy moth story on Page 4

Information Retrieval: A Key to Progress

Researchers all agree on one thing: Information is meant to be used. When valuable data is allowed to gather dust on a remote back shelf, science suffers.

ARS scientists know that timely, accessible information is often the key to a successful mission, and work diligently to stay abreast of publications in their fields. Yet this job could be easier—particularly in terms of rapid information retrieval.

On March 20, I signed a letter of understanding with the National Agricultural Library in Beltsville, Maryland, that will take us another step into the information future. The agreement will help NAL make its 2.1 million volumes more readily available to our scientists throughout ARS' 130 U.S. and overseas locations. I strongly urge that all in ARS participate in this effort to make better use of the national library and of the substantial reference material already in the agency libraries.

Our relationship with NAL, the world's largest agricultural library, has always been close. One of the library's key information aids, the Current Awareness Literature Service (CALS), provides more than 85 percent of its USDA responses to ARS users.

ARS scientists can access NAL's AGRICOLA database, which contains over 2.7 million citations, via CD-ROM or online. The most current AGRICOLA records will be soon available on ISIS (Integrated System for Information Services), NAL's online catalog. Under a cooperative program with NAL, ARS researchers have sent the Library lists of their publications to ensure inclusion of these citations in AGRICOLA.

Considering the already heavy use of NAL's facilities by our scientists, steps to speed up the process should have substantial payoffs in meeting research objectives.

ARS' 24 libraries vary markedly in automation. Some locations still have holdings represented in card catalogs, while others have a combination of cards and computer databases. In some cases, the computerized catalogs may be incompatible with one another.

Under the agreement, ARS libraries will be able to contribute records to and access NAL's online catalog. NAL will furnish computerized catalog services to these libraries. This will improve communication among ARS sites and with NAL. It will also eliminate substantial duplication of effort among the locations when they catalog new acquisitions.

NAL will furnish onsite training at some locations and provide training materials at others to help ARS librarians and scientist-users make use of the electronic services available.

Library material at the ARS locations will be integrated into a nationwide loan program. For example, a scientist at our Beckley, West Virginia, lab could access the online catalog, ISIS, from one of the lab's computers and, on finding one or more suitable publications, make a request for loan or photocopy. The request would be routed to the facility best able to provide document delivery—be it an ARS library or NAL.

While NAL usually fills requests for materials within 2 days, the user in the past has had to wait for the postal system to deliver the request and return the requested materials. Under the agreement, ways will be sought to deliver documents electronically by means such as via fax or electronic mail.

NAL will coordinate development and maintenance of guidelines for a manual of operating procedures for functional interactions with ARS libraries and laboratories.

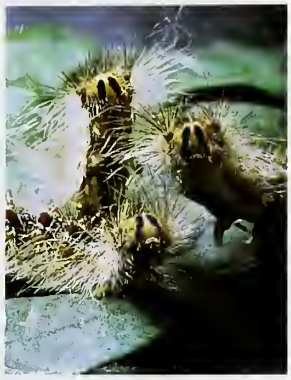
In cooperation with ARS researchers and library staffs, experts in the field of retrieval will assess the information needs of ARS programs. NAL will recommend new and/or enhanced programs, products, and services for meeting those needs.

Under the agreement, ARS will encourage researchers who have valuable agriculturally related collections to donate them to NAL on retiring or at other appropriate opportunities.

Both organizations agree to take a look at what we have accomplished and what still needs to be done each year. This will serve as the basis for a review of the relationship between NAL and ARS libraries and the research laboratories. The goal is to give every researcher access to the library of the future as quickly and directly as possible.

R. Dean Plowman
Administrator

Agricultural Research



Cover: Gypsy moth larvae. Adaptable and ever hungry, this pest is turning up in more and more areas around the country.
Photo by Michael Pendrak

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USDA/APHIS

Gypsy Moths

Thwarting Their Wandering Ways

Low-flying airplanes, tree girdles made of burlap, and disgruntled homeowners peering skyward as chewed leaves float down from almost leafless trees. Thanks to the gypsy moth caterpillar, the wormlike larval stage of the *Lymantria dispar* moth. these are all familiar sights in summertime suburbia.

The pest was accidentally released in 1869 at the home of Etienne Leopold Trouvelot, a well-meaning, self-appointed entomologist who brought gypsy moth eggs from his native France. He'd hoped to produce a disease-resistant silkworm for America. Instead, he produced angry neighbors in the little Massachusetts town of Medford; within 20 years of Trouvelot's mishap on Myrtle Street, their trees were being eaten leafless.

And, like all organisms out of their native territory, the gypsy moth had virtually no natural enemies here; it could munch leaves to its heart's content. And munch it did—until, by 1923, all of New England was infested.

Like all butterflies and moths, the gypsy moth passes through four distinct stages: egg, larva, pupa, and adult. The larva's leaf eating results in a caterpillar too big for its skin, so each one grows a new cuticle and sheds the old one. Called molting, the process occurs four times in males and five in females. Depending on the area of the country, the molting and leaf-chewing occurs somewhere between the end of April and June.

All larvae eventually pupate for about 2 weeks. When they emerge as adults, they do nothing but reproduce: no eating and, in the case of females, virtually no flying. The females sit on

In periodic outbreaks, gypsy moth caterpillars defoliate millions of acres of forest trees. A single gypsy moth (inset) can produce up to 800 eggs.

trees, emitting a sex pheromone to attract the smaller, bark-colored males. Males respond, and mated females soon deposit a mass containing between 100 and 800 eggs.

To deter predators and to insulate them for the winter to come, the eggs are encased in a secretion produced by the female, along with scales and hairs from the underside of her body. Homeowners may spot these egg masses on their shade trees, as well as lawn furniture, sand boxes, swingsets, and even the sides of their homes. On park land, hikers may notice them on trees or rocks—the beige masses are usually about the size of a quarter.

Not a Picky Eater

A gypsy moth caterpillar can chew the leaves of more than 500 species of trees and shrubs, though its most important meal of choice would be an oak leaf. During its 40-day life, it eats 4 to 10 leaves.

Severely infested trees often become completely defoliated, or leafless. Three years of complete defoliation is usually enough to kill a tree; evergreen, young, or weak trees may succumb in just 1 year.

USDA/APHIS

Although its favorite meal is an oak leaf, this gypsy moth larva will eat leaves of more than 500 species of trees and shrubs.

Currently, the moth infests 13 million acres throughout the Northeast and has spread south to North Carolina and east to Ohio. Michigan is the worst victim in the Midwest. California, Oregon, Washington, Utah, and Colorado have had pocket infestations, colonies unwittingly begun by people moving from the East.

Since just 1960, the gypsy moth has spread at the rate of about 10 miles per year. For that reason—and because gypsy moths already appear in several different pockets across the nation—officials fear they could soon become a nationwide problem.

That's why the Agricultural Research Service, Forest Service (FS), and Animal and Plant Health Inspection Service (APHIS)—all agencies of the U.S. Department of Agriculture—are researching in earnest to find moth-squelching methods.

FS aims to control the pest in our nation's forests, while APHIS seeks to limit its spread by eradicating isolated infestations. ARS meanwhile focuses research on protecting trees in nonforest environments, such as parks, communities, and down Main Street, USA.

Says Ralph A. Bram, national program leader for gypsy moth research, "Our policy is to research gypsy moth management for nonforest environments and to support the agencies actively fighting them." He adds, "We have a tremendous level of cooperation within the USDA agencies, as well as with state institutions working to manage the gypsy moth."

This year, according to Bram, ARS is spending more than $1.3 million on gypsy moth research, carried out at three locations in the United States plus one in Behoust, France, and another in Seoul, Korea. The U.S. sites are Beltsville, Maryland; Ithaca, New York; and Newark, Delaware. Most of the work is based at Beltsville.

Bash Them With Biology

The research has three main features: biologically based methods of management, developmental biology, and management systems for homeowners and suburban parks.

Nature offers scientists several different modes of pest control. In the case of the notorious gypsy moth, ARS is striving to take advantage of all of them.

One promising method: reestablish the natural balance between an organism and its enemies. So scientists often travel abroad in a pest's homeland in search of its natural enemies—parasites, predators, and diseases. But first they must overcome the inconsistencies and obstacles that arise whenever one depends on a live organism to behave predictably.

Entomologist Paul Schaefer, of the Beneficial Insects Introduction Laboratory in Newark, Delaware, has hopes for a wasp that attacks gypsy moth pupae. Called *Coccygomimus disparis,* this native Japanese parasitic wasp was sent here by ARS' Asian Parasite Laboratory. The Newark lab has also received wasp samples from entomologists in India.

Newark scientists first quarantined the wasps to make sure they were safe for release. Then, cooperating with scientists from other state and federal agencies, they made releases on the East Coast in the late 1970's. The scientists didn't see any sign of the wasp for a few years, as often occurs in attempts to establish biological control agents.

In the early 1980's, the wasp began to show up in widely separated locations. But in the last 2 years of cooperative work with Delaware State College, the group has gained results that are increasingly encouraging. Although in 1989, they found just one wasp in one spot—and only

USDA/APHIS

Gypsy moth male.

one-tenth of a percent of collected caterpillars were found to have parasites in them—by 1990, wasps had made an appearance at 11 different sites in the same region. The researchers found 97 specimens, and the level of parasitism had jumped to 4 percent.

"Anything over 10 percent is considered highly promising," says Schaefer. The researchers will monitor the peninsula for another 3 years to see whether populations of the wasp continue to build.

Another enemy under study at the lab is *Calosoma sycophanta.* The predator beetle was first sent to USDA scientists by European entomologists in 1905, and by 1910 over 4,000 had been imported. This beetle promptly established itself in New England and has been expanding its range ever since. "It's very good at climbing trees in search of gypsy moth larvae to eat," says lab director Roger Fuester.

Both larvae and adults of this species attack gypsy moths, the beetle larvae feeding primarily on moth pupae, the adults on caterpillars. But, Fuester explains, "This enemy always lags behind gypsy moth buildups. The beetle larvae don't become abundant until the year you get the worst defoliation—then suddenly, there they are." What that means, then, is that adult beetles—which eat the most gypsy moths—are not plentiful until the following year, when it's more or less too late.

"We're seeing if we can release adults when they're very scarce so they can attack building populations of gypsy moth," Fuester says.

The adults, he adds, live a very long time for insects—up to 4 years. So one adult can help control the pest for several years in a row. "We could learn to augment the population of adults when it falls too low to avert a future outbreak of gypsy moths."

A bit smaller than a pencil eraser, the wasp *Glyptapanteles flavicoxis* was discovered by cooperating scientists in India, where it feeds on a related gypsy moth species. It was imported by USDA entomologists and repeatedly released for many years—but each time failed to become established. Reviewing their previous attempts, scientists realized only adult insects had been released. Last season they instead released parasitized gypsy moth larvae. To their delight, some of the parasites developed within the caterpillars and emerged to become adults.

But until the end of this season it won't be possible to tell whether or not wasps survived over the winter to expand their population. "If we find the wasp this year," Fuester says, "it could mean we have a new release strategy to help it get established."

A new release strategy and, for another wasp of the same genus, a new climate. *Glyptapanteles porthetriae* never did well in New England and the mid-Atlantic states. So scientists at the Newark lab where a new shipment has just come in, will test them in the Carolinas and Georgia—a climate more like their homes in southern France, Spain, and Yugoslavia.

"This wasp might be very useful as the gypsy moth expands its range farther south," Fuester says.

Both the European Parasite Laboratory and the Asian Parasite Laboratory continue to explore for parasites and predators of other pests, as well as the gypsy moth.

The Pheromone Zone

Another opportunity to exploit biology for pest control is use of a pest's natural sex attractant—its pheromone. For gypsy moth, a synthetic version of the female's sex pheromone—disparlure—has been helping state and federal officials detect the presence of moths since the early 1970's. Disparlure baits about

DWIGHT LYNN

Gypsy moth cells infected with the Abington strain of a nuclear polyhedrosis virus (yellowish-brown cube-shaped bodies).

300,000 traps used in federal and state programs.

The traps are equipped with pheromone-impregnated plastic strips. Thanks to a controlled-release formulation, they emit scent over the entire flight season of the gypsy moth.

Because the current pheromone strips are available from just one source, officials with FS and APHIS are seeking a competitor dispenser. So ARS chemist B.A. Leonhardt and colleagues evaluated those of other manufacturers, but none worked as well as the laminate strip. The

BOB BJORK

Leafless trees in midsummer attest to the gypsy moth caterpillars' appetite.

problem: Either the chemical came out too fast, so it didn't last the whole flight season, or too little came out to attract moths.

Leonhardt decided to formulate a new strip herself. Research with colleague E. David DeVilbiss at the Insect Chemical Ecology Laboratory and Victor C. Mastro of APHIS' Otis Methods Development Center in Massachusetts yielded a new disparlure-impregnated dispensing system that is easier and cheaper to manufacture. In lab and field tests, the new dispenser was as effective as the laminate dispenser currently used.

This season, ARS is cooperating with FS and APHIS to test the strips in 1,000 detection traps. Then, Leonhardt hopes to further expand operational tests next year.

If it proves to work as well as the laminate strip, Leonhardt predicts that companies will submit bids to supply federal agencies with the 300,000-400,000 they need each year. Already, several companies have expressed interest in licensing the technology.

"Our goal was not to replace the currently used dispenser, but to offer an alternative," Leonhardt says. The three scientists have applied for a patent on the invention.

Another strategic use of the pheromone is to disrupt mating by spreading confusion, and to this purpose Leonhardt has evaluated a new dispensing method for another version of the pheromone that is easier and cheaper to make. Still in an experimental stage, this kind of disparlure is used by FS and APHIS to permeate an entire forest. The substance masks the scent emitted by female moths.

The alternative disparlure is dispensed from airplanes by special hoppers that broadcast small chips of pheromone-impregnated plastic laminate.

A company called AgriSense in Fresno, California, sent Leonhardt several new types of polymeric microbeads containing this formulation, called racemic disparlure. These tiny impregnated microbeads can be distributed with normal aerial spraying techniques. "This reduces the cost of using mating disruption in two ways," Leonhardt explains. First, it makes application easier, because agencies don't need to hire only airplanes with special application equipment; conventional spray planes could do the job. Second, an alternative formulation once again increases competition among companies who want to bid for the job.

To see if mating disruption has occurred, officials simply put virgin females in mating stations. If the local males are too confused by disparlure to find these females and mate with them, it is assumed that indigenous females are also untouched. This season, AgriSense, ARS, APHIS, and FS are cooperating on a 500-acre study comparing the beads and laminate chips.

Mating disruption as a technique is still under scrutiny, Leonhardt says.

But if continued experiments show that it works, the beads may provide a good alternative for dispensing racemic disparlure.

Dear Abby

Probably one of the most promising research accomplishments in gypsy moth work to come out of ARS is a nuclear polyhedrosis virus (NPV) nicknamed Abby. In 1982, ARS entomologist Martin Shapiro was conducting tests to see how well 19 varieties of nuclear polyhedrosis viruses from around the world would kill gypsy moths. He found that a native one, from Abington, Massachusetts, was one of the best and he fondly named it Abby. In a few years, Abby may well bring us a natural, environmentally friendly control for gypsy moth.

Over and over, Shapiro infected gypsy moths with the Abby virus, selecting those strains that killed the most caterpillars in the shortest time.

What he got was a strain that was about 10 times more potent in laboratory tests than the standard Gypchek, the registered gypsy moth NPV.

But there were problems.

First, ultraviolet rays produced by the sun quickly degraded the virus and reduced its kill ability. So Shapiro set about to find sunscreens for Abby. He tested human sunscreens, dyes, B vitamins, and plant pigments, among others. He had found 100-percent protection with just 1 percent congo red dye, but investigation into earlier research on congo red revealed that it can cause tumor growth.

Back to the drawing board. This time, the best overall protection was afforded by a fluorescent whitener, "the stuff in laundry bleach that makes whites whiter and brights brighter," Shapiro says. In addition to absorbing ultraviolet rays, thus keeping them from the virus, the brightener has the added benefit of mysteriously enhancing the virus' effectiveness.

Why? "We don't know," Shapiro says. "We're trying to find out, but for some reason the brightener reduces the amount of virus and amount of time needed to start an infection." The scientists don't expect any impediments to using the whitener since it is already so widely marketed.

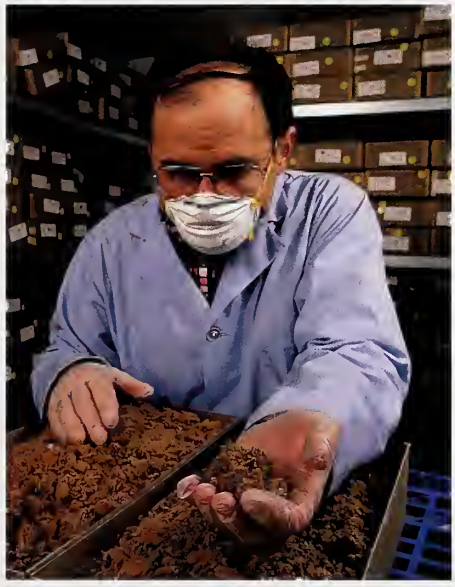
Shapiro has applied for patents on both the Abby strain and use of the fluorescent brightener as an ultraviolet protectant and enhancing substance.

The next problem faced by ARS researchers was to produce the virus in a cost-efficient way. NPV grows just fine in lab-reared caterpillars, but any company interested in manufacturing it would also have to house and feed those caterpillars. While this is feasible, large-scale producers favor a growth medium such as a gypsy moth cell culture.

American Cyanamid of San Leandro, California, has signed a cooperative research and development agreement with entomologists Edward Dougherty, Dwight Lynn, and Shapiro, all of the Insect Biocontrol Laboratory in Beltsville, Maryland, to develop a virus production system. Previously, Dougherty, and Kathleen Shields of FS in Hamden, Connecticut, had recognized the need for more gypsy moth cell lines for virus replication studies. They asked Lynn, who has developed a variety of insect cell lines, to help them meet their needs.

Their goal was to find a line in which Abby would grow and flourish but that would be cheaper and easier to maintain than a living caterpillar. So far, they have derived a line of cells from the insect's fat-producing structure that is almost good enough for commercial use.

BOB BJORK



Entomologist John Tanner examines gypsy moth egg masses in cold storage. (K-2555-15)

Back to Basics

At the Insect Neurobiology and Hormone Laboratory in Beltsville, Maryland, five researchers are studying basic brain and reproductive functions in the gypsy moth. Headed up by entomologist James Svoboda, this group is isolating and identifying brain proteins, called neuropeptides, that control production of molting and reproductive hormones. Molting hormones are essential for insects to pass from one stage of larval development into another, increasing their size as they do so.

"Having the chemical structure of the proteins will help us pinpoint the gene that causes the insect to produce those proteins," says physiologist Thomas Kelly.

Once they find the gene, the scientists would insert it into a virus—perhaps a baculovirus, depending on the gene. Then, that virus would infect the gypsy moth and cause it to produce the peptide hormone, which is the natural thing for it to do—except that the time or

amount would be different from what nature intended.

"Inordinate amounts of normal or modified neuropeptides at the wrong time could severely upset development of the insect," Svoboda says. Or nonpeptide inhibitors might be synthesized that specifically interfere with neuropeptide biosynthesis or biological activity.

The ultimate goal—a baculovirus genetically engineered to infect a gypsy moth with large amounts of brain proteins that disrupt its normal molting hormone production—is probably years away.

Saving Our Parks and Shade Trees

No discussion of gypsy moth control can be complete without mention of the debate over two of the most popular treatments currently in use: *diflubenzuron* and *Bacillus thuringiensis.*

Diflubenzuron, a growth regulator, has traditionally provided reliable control of gypsy moth at extremely low doses. But it has long come under fire because of concern for aquatic organisms. Since many aquatic organisms are closely related to insects, they have many similar physiological processes. Many fear diflubenzuron's action—halting molting—may have the same effects on crabs, shrimp, lobsters, and other crustaceans.

For that reason, the Environmental Protection Agency prohibits—on the product's label—the use of diflubenzuron near bodies of water. However, environmental groups still fear that diflubenzuron used in suburban areas or in parks may reach aquatic environments.

Bacillus thuringiensis (Bt), a naturally occurring bacterium, kills a variety of lepidopteran insects. A major objection, however, has been that it sometimes fails to provide reliable or consistent protection from defoliation. And to kill gypsy moth caterpillars, communities have felt the need to apply Bt at least twice.

In 1989, ARS entomologists Ralph E. Webb, Richard L. Ridgway, and Kevin W. Thorpe met with the Maryland Department of Agriculture and county and local officials to develop a strategy that would render Bt a cost-efficient and effective control method for gypsy moths.

After research conducted over three seasons in Montgomery County, Maryland, Webb says "one application of Bt, well-applied, can possibly handle all gypsy moth populations."

But, he says, there are times when a second application—applied over selected areas of a park or community—is needed to protect an area as effectively as diflubenzuron does.

How do managers select those areas? They count egg masses. Generally, one application is enough when there are low densities of egg masses, while higher densities warrant a second application. "The key to this program is to monitor the population so that you know where to apply once and where to apply twice," Webb says. Managers should count egg masses during the winter before larvae emerge to feed. "Then they can plan how many times to have the planes go up and spray Bt," he says.

"The monitoring may indicate that just 20 percent of the area requires a second application," Webb says. If that's the case, the county can save the cost of automatically respraying the other 80 percent.

In the tests, the program offered "an acceptable level of control," Webb says. Basically that means that the trees were less than 30 percent defoliated.

Webb stresses that while one application may protect the foliage, a second "buys you population suppression, which helps for the following years."

And on the homeowner front, Webb has evaluated how well different available control methods save our shade trees.

One option—calling a tree service to spray registered insecticides such as synthetic pyrethroids—will control the moth.

"Treatment with the chemical will give you beautiful protection the rest of the season." However, Webb cautions that trees have other insects, such as scale, that severely harm them, and broad-use insect killers kill natural scale enemies.

He sums it up: "There is a good scientific reason to take a softer approach and risk a little bit of gypsy moth damage."

USDA/APHIS

***Bacillus thuringiensis* glints in the early morning sunligh as it is sprayed in this forest.**

CHUCK HERRON

Families vacationing in gypsy moth areas during late summer and fall may return home with hitchhiking egg masses on their campers and travel trailers. Within a few seasons, a single quarter-dollar-size egg mass can become millions of leaf-devouring gypsy moth caterpillars.

His softer approach is illustrated by tree banding. Webb ran a modest experiment at his home in Greenbelt, Maryland, last season. He made a sticky barrier band on his willow oak using duct tape covered with tree tanglefoot—a natural mixture of tree gums and resins. The sticky tanglefoot on the band prevented larvae from going up the trunk to the leaves.

Three times a day, Webb diligently removed larvae that had gathered below the band. He estimates that the band prevented 20,000 larvae that season from feeding on that one tree. The result: virtually no damage—less than 1 percent defoliation.

People who rely on bands alone will get good protection, around 5-30 percent defoliation, as long as the tree is isolated from other infested trees. "Thirty percent defoliation won't harm the tree, although it may strike the homeowner as an unsightly nuisance."

The better the seal between band and trunk, the better the protection, Webb says. "Some oak species have very shaggy bark; there's really an art to getting the band on so that it's completely sealed."

Homeowners have tried peanut butter, petroleum jelly, and axle grease as the barrier material. But some of these melt with heat and, in the case of axle grease, may harm the tree if it runs off the band and onto the bark. He recommends tree tanglefoot; it is natural and doesn't melt or harm bark.

Webb emphasizes: Homeowners must get the bands up before eggs hatch!

"The farther north you go, the later you can be putting them up," Webb says. "The deadline in Pennsylvania or New York is May 1, for example, and in Virginia it's April 1. In my home state of Maryland, that's mid-April. I make sure I have my bands up when I send in my income tax."—By **Jessica Morrison Silva,** ARS.

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Dwarf in Size, Giant in Productivity

When is bigger not better? When more size takes up too much space, time, energy, and costs extra money. This is certainly the case with standard apple trees, says Miklos Faust, head of ARS' Fruit Laboratory, as he goes on to describe some of the advantages of dwarf trees that flourish at the Beltsville Agricultural Research Center.

Being smaller, they are easier to prune, easier to spray, and easier to harvest. They also bear fruit earlier than large trees. Fruit from a dwarf tree is just as large as an apple grown on a full-size tree and cannot be distinguished in other respects.

In the early 1900's, growers were interested mainly in big trees that produced lots of fruit. With plenty of wide open space, they had little concern for tree densities and pounds of apples per acre.

But time has changed all that.

"Just in the last 10 years, we've seen prices for orchard land rise 400 percent in our area. Despite a doubling of wages, qualified pruners and pickers have become almost impossible to get," Faust says. "And consumers are much more demanding when it comes to fruit quality and appearance."

To survive in today's economic and consumer-oriented climate, growers must lower their costs with higher density orchards and smaller trees.

Faust says that dwarf trees, which get about 7 feet tall, are easier to manage than the 14-foot-or-more full-size trees. Ladders or special equipment aren't needed to prune or

RICHARD NOWITZ

Plant physiologist Miklos Faust (right) and laboratory technician Adrienne Labega count blossoms on a 7-year-old semidwarf apple tree propagated from tissue culture. (K-4048-17)

harvest trees. Even spraying is more efficient with the smaller, denser trees.

"Growers plant about 150 regular-size apple trees on an acre of land. They could plant anywhere from 600 to 1,000 dwarf trees in the same space," Faust says.

Then why aren't more growers planting dwarfs?

One reason is the cost of trees. Today's dwarf apple trees don't grow on their own roots but are grafted onto special rootstocks.

"Planting 1,000 grafted trees per acre is very expensive—sometimes it runs 2 or 3 times the cost of the land," says ARS' George L. Steffens.

Steffens, a plant physiologist at the Fruit Laboratory, says, "Dwarfing rootstocks are not well-adapted to our East Coast environment. The roots are smaller, so they're susceptible to water stress, and require irrigation, which increases costs even more.

Another reason is that the roots of dwarfing rootstocks are usually small, making it hard for them to support even a dwarf tree when the tree bears fruit. Thus trees must be propped up with stakes or trellises, which does add an extra investment expense for the grower.

"What we really need are less expensive trees," Steffens says.

And that's what Richard H. Zimmerman and Ingrid Fordham, plant physiologist and horticulturist at the Fruit Laboratory, are studying . They're working on a new type of orchard that is based on tissue culture propagated trees that are dwarfed by new methods.

The lab already boasts the oldest and perhaps the largest apple orchard made up exclusively of tissue-cultured trees—although of standard size.

Fruit lab plant physiologists say that starting or replenishing an orchard with tissue-cultured trees is much more cost effective than using grafted trees.

RICHARD NOWITZ

Miklos Faust and Adrienne Labega examine one of the lab's 12-year-old dwarf apples. (K-4048-14)

"We can potentially harvest 40 apple trees from a 16-ounce jar," Fordham says. These micropropagated apple trees could cost a grower under $2 each compared to about $5 for a tree grafted onto a rootstock.

"Using shoots from existing cultures, the rooting process can usually be accomplished in about 4 weeks," explains Zimmerman. After the plants are grown in the greenhouse for a couple of months, they're ready for the field. This compares with the 3 years a tree spends at various stages in a conventional nursery.

The problem, he says, is that own-rooted trees usually develop into full-size trees. This is why Steffens' work with dwarf trees is so important. If they can identify the genetic trait that controls dwarfing, then it may be possible to transfer that trait into commercial varieties that can be propagated with tissue culture.

Working with the Long Ashton Research Center, University of Bristol in England, Steffens is trying to determine the role of naturally occurring gibberellic acid (GA) in tree growth.

"More than 80 different natural gibberellins have been identified. We're focusing not only on the amount of specific GA, Steffens says, but also on the ability of the plant to use this growth regulator under different environmental conditions, especially temperatures."

Steffens is experimenting with other growth regulators to control the vigorous growth of tissue-cultured trees.

"We've successfully used growth regulators to reduce vegetative growth of several apple varieties," he says.

The growth regulators limit the supply of gibberellic acid to the growing shoots. They also seem to increase flowering and fruiting, a finding Steffens is further investigating with ARS chemists from the Western Regional Research Center in Albany, California.

"These growth regulators could potentially be used to help manage own-rooted, tissue-cultured trees under orchard conditions," Steffens explains.—By **Doris Stanley**, ARS.

Scientists mentioned in this article can be contacted at the USDA-ARS Fruit Laboratory, BARC-West, 10300 Baltimore Ave., Beltsville, MD 20705-2350. Phone (301) 344-3567. ◆

Cutting Energy Costs for Irrigation

A computer program cut power consumption by irrigation pumps up to 20 percent—a savings that translates into more efficient food production and significant energy conservation.

Where irrigators use a pipe network to move water from multiple pumps to several center pivot sprinklers, cutting energy costs can be difficult and very laborious. Many combinations of pumps are possible to maintain the minimum flow and pressure as various pivots are turned on or off, depending on crop needs, but only one pump combination is the most energy efficient.

"The program we wrote calculates how much pressure is required from pumps to move water to center pivot sprinklers that the irrigator needs. If irrigators don't know the minimum pressure they need, it's often the case that they will use too much and drive up their energy costs," says ARS' Dale F. Heermann, an agricultural engineer stationed at Fort Collins, Colorado.

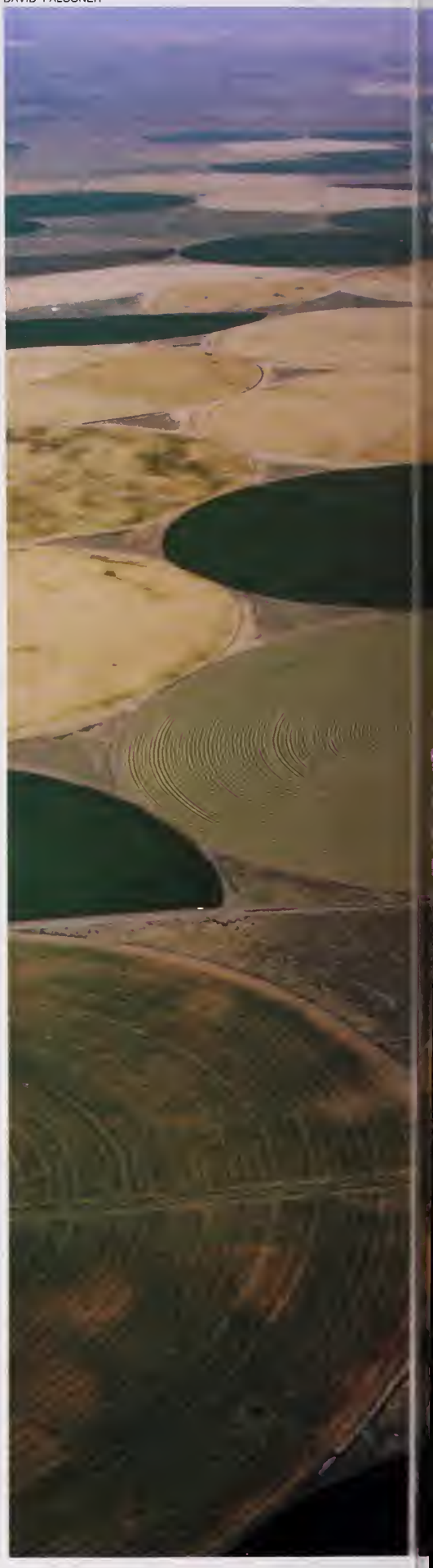
Electricity costs for large users can total thousands of dollars a month. Bills are based, as for private homes, on how much was used during the month. Like individual consumers, large users, including factories and farm irrigators, are billed according to peak demand for the billing period. The larger the peak demand, the more electricity costs.

"The computer knows the individual performance characteristics of each pump in the system and keeps track of the peak electrical demand of each pump station during the billing period," says agricultural engineer Gerald W. Buchleiter, also at Fort Collins. "The computer recommends the pump combination that can supply the minimum pressure needed for the operating pivots and at the least cost for that billing period."

DAVID FALCONER

Above: Each center-pivot sprinkler irrigates about 128 acres. (K-3015-3)

DAVID FALCONER



Right: Over 100 center-pivot sprinklers, controlled by a central computer, irrigate wheat, alfalfa, potatoes, and melons along the Columbia River near Hermiston, Oregon. (K-3016-8)

Mercer Ranches near Paterson, Washington, has used the program since its release about 5 years ago. That operation lifts water about 450 feet from the Columbia River to irrigate 3,500 acres of potatoes, carrots, sweet corn, and asparagus. Six pumps at the main pump station, ranging in size from 600 to 1,500 horsepower, plus two pumps at a booster station, deliver water through nearly 15 miles of underground pipeline to 33 pivots.

"The program is especially valuable for regulating our variable-speed pumps to just barely meet minimum water pressure requirements of the system. However, implementing the recommendations under changing conditions was difficult because of the time it took to drive nearly 7 miles to make the necessary changes at the main pump station," says Dick Beightol, vice president of plant operations.

Last summer he purchased a radio telemetry system to control the pumps and to monitor a critical center pivot where it is difficult to maintain the correct pressure.

As Beightol makes irrigation changes from his pickup truck, he also keys in information about the pivots into a portable, battery-powered computer. The computer program recommends the least-cost pump combination and Beightol sends the appropriate commands to the main pump station via radio signal.

"The ARS program also offers help in designing new irrigation systems and improving old ones. By plugging in different pump designs and delivery paths, irrigators and engineers can learn the least expensive way to deliver water from a well or river to fields," says Heermann.—By **Dennis Senft,** ARS.

Dale F. Heermann and Gerald W. Buchleiter are at the USDA-ARS Agricultural Engineering Research Center, Colorado State University, Fort Collins, CO 80523. Phone (303) 491-8229. ◆

Making the Plant/Soil/Nutrition Connection

CORNELL UNIVERSITY

A big step toward understanding biology's ultimate mystery—how do cells make protein, the building blocks of life?—came in 1965 when a team of five ARS and three Cornell University scientists determined that the molecular structure of one of the RNA's , ribonucleic acid. The achievement won the research team's leader Robert W. Holley a share of the 1968 Nobel Prize for Medicine or Physiology. Team members (left to right): Robert Holley, Jean Apgar, James Madison, John Penswick, George Everitt, and Susan Merrill.

Even though a pound of chuck roast sold for less than two bits and a pound of navy beans was barely more than a nickel, 1935 was a time when many Americans were malnourished.

Senator John Hollis Bankhead II joined forces with Representative John Marvin Jones of Texas to push passage of the Bankhead-Jones Act on June 29, 1935.

Among the provisions of this act was the establishment of nine regional agricultural research laboratories, including one at Ithaca, New York.

The Ithaca lab—the last of the nine to be funded—had a unique mission: to trace the nutritional connection between soils, plants, and animals. The idea was that improvements to the soils might send beneficial ripples all the way up the food chain.

Funding for what is now the U.S. Plant, Soil, and Nutrition Laboratory was approved by Agriculture Secretary Henry A. Wallace on January 31, 1939. By the end of July 1940, the lab was settled into its new home on Tower Road on the edge of the Cornell University campus, and the search for answers was on.

Today, as the lab completes its first half century, it has many scientific successes—and one Nobel Prize winner—to its credit.

And after 50 years, the lab is busier than ever, according to research leader Darrell R. Van Campen. "This actually may be the only lab of its kind in the world," he says.

The concept behind the founding of the Ithaca lab—the thought that soils could affect the plants that sprouted in them—was considered quite novel in the 1930's according to Kenneth C. Beeson. Now retired and living in Sun City, Arizona, Beeson was a research chemist for the U.S. Department of Agriculture in the late 1930's and went on to be laboratory director of the Ithaca facility from 1949 to 1960.

"In the 1930's, throughout the United States, more attention was being given to the nutritional quality of foods, with particular attention to nutrient elements such as calcium," Beeson recalls.

"A number of people in agricultural experiment stations were analyzing garden produce and finding, for example, that lettuce in Florida might have a different calcium content than lettuce grown in Mississippi."

Beeson's link with the Ithaca lab technically predates the lab itself. While working for USDA's old Bureau of Chemistry and Soils in Washington, D.C., Beeson was assigned in 1937 to begin reviewing world literature on the link between nutritional value of foods and the quality of the soil in which the food was grown.

By the fall of 1940, Beeson had moved to Ithaca to work under the direction of the lab's first research leader, Leonard A. Maynard. Maynard held the reins until 1945 but only served on a part-time basis; he was also director of Cornell University's School of Nutrition.

Across the span of dozens of years and research projects, Beeson still holds a vivid image from those early days in Ithaca.

"The first big project of the lab, by Karl C. Hamner and associates, was a study of fertilizer's effect on carotene content of tomatoes," Beeson says.

"In the spring of 1941, pots of sand covered the entire greenhouse area to test a wide range of fertilization on the tomato's levels of carotene and ascorbic acid. It was a beautiful sight—that big area with pots all growing tomatoes."

The pace was quick at the Ithaca facility. James T. Jardine, chief and director of research for USDA's Office of Experiment Stations, listed many accomplishments in the lab's first annual report, submitted to Agriculture Secretary Claude R. Wickard in October 1941.

Along with mentioning the "several thousand tomato plants," Jardine reported on how the lab, in cooperation with Cornell University, had already discovered that alfalfa grown on soil low in boron contained 20 percent less carotene than alfalfa grown on soils with abundant boron.

In addition, Jardine wrote, the lab had determined that vitamin B_1 content of food could be determined by a fungus assay that was much quicker than previous methods.

KEITH WELLER

The goal of chemist Darrell Van Campen (shown checking growth of young soybean plants) and other researchers at the U.S. Plant, Soil, and Nutrition Research Laboratory is to improve the nutritional quality of food and feed plants. (K-4039-14)

Karl C. Hamner—he of the thousands of tomato plants—succeeded Cornell's Maynard as laboratory director at the Ithaca lab in 1946 and served until 1948, when Beeson took the helm.

Beeson left Ithaca in 1960 to tackle an international research project in the Sudan. His successor as research leader was William H. Allaway, better known to many as "Hub," who served as lab leader until 1976.

Allaway, a veteran of USDA's old Bureau of Plant Industry, had joined the Agricultural Research Service in 1954, the year after ARS was established to administer USDA research.

As laboratory director at the Ithaca facility, Allaway oversaw addition of a wing to the lab, providing much-needed working space for the scientists. The addition was completed in 1963.

On board when Allaway arrived was one Robert Holley, already the co-discoverer of soluble ribonucleic acids (RNA) in protein synthesis.

"It was obvious Holley was on to something pretty important," Allaway says. Time proved Allaway right; in 1968 Holley won the Nobel Prize in Physiology and Medicine for determining the structure of one of the soluble ribonucleic acids, a building block of modern genetic engineering.

The work begun by Holley, now living in La Jolla, California, has been carried in a new direction by plant physiologist John F. Thompson and research chemist James T. Madison.

Madison had worked with Holley on the RNA research, and he and Thompson thought they could combine the knowledge gleaned from those days with newly developed genetic engineering techniques to improve the nutritional quality of plants.

When compared with animal proteins such as those in meat, milk, and eggs, the protein from soybeans and other legumes contains relatively

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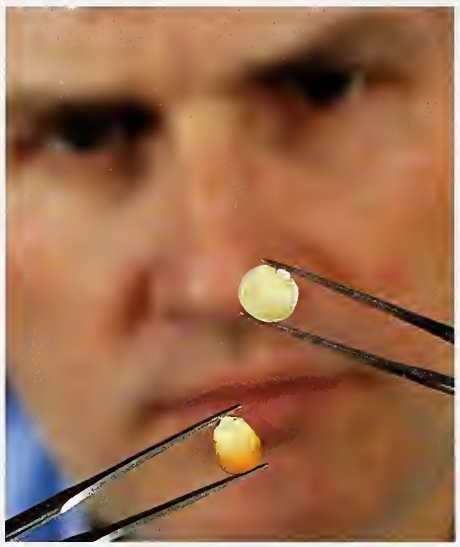

Plant physiologist Ross Welch compares an unusual Mexican white corn (top) that contains a high-lysine gene with a kernel of commercial yellow corn. Lysine is an essential amino acid. (K-4038-1)

low concentrations of the sulfur-containing amino acid methionine.

The ability of humans and nonruminant animals to utilize legume seed protein is limited by the concentration of sulfur amino acids in those seeds. Once all the sulfur amino acids have been used up, the remaining protein in the seeds is wasted.

Thompson and Madison have concentrated on boosting the amount of methionine in legume seeds, with some success. They have developed techniques that increase the amount of a specific "storage protein" in soybeans that is richer in methionine than other storage proteins, consequently increasing overall methionine content in the beans.

While their technique works well in the lab, it is not yet feasible for commercial soybean production. But the two scientists are now trying to develop a special gene that could be introduced directly into soybeans to increase their content of sulfur-amino acids—and, in turn, their nutritional quality.

Dietary concerns of a different sort occupied the research hours of "Hub" Allaway in his years at the Ithaca facility.

"Selenium toxicity had been a longstanding problem in grazing animals on the Great Plains and in the western United States," Allaway says.

"I worked on selenium research for 12 years. When I started, it was illegal to add it to animal feeds. Now that's routinely done. Our contribution was telling the Food and Drug Administration that by adding selenium to animal feeds in areas where selenium was deficient in the soil, you weren't doing anything that wasn't happening naturally through plants in areas where selenium was adequate in the soil."

Another high point in the history of the Ithaca lab was the production in the 1940's of a map showing the distribution of the mineral cobalt in the soils of the eastern United States.

"For example, there is an area of New Hampshire where the soil was formed from granitic rock, and it contains almost no cobalt," explains Darrell Van Campen, research leader at the Ithaca lab since 1979.

"In that area, grazing animals just didn't do well because of cobalt deficiencies. Cattle and sheep didn't grow well there, and they didn't reproduce well. Ruminant animals such as cows have bacteria in their rumens that use cobalt to make vitamin B_{12}, so they must have cobalt.

This lab didn't discover cobalt was an essential element; that came out of Australia in the mid-1930's. But Kenneth Beeson and his group suspected cobalt deficiencies might be the problem in the Northeast, so they went in and sampled the soil and came out with the map showing where it was deficient.

"Today, livestock producers in that area supplement their animals' feed

KEITH WELLER

Chemist James Madison (left) and plant physiologist John Thompson inspect a film autoradiograph, which shows that methionine increases the level of messenger RNA for Bowman-Birk protease inhibitor. (K-4043-4)

with cobalt, and dairy cattle, beef cattle, and sheep do very well there."

The Ithaca lab has since produced similar maps showing the disposition in soil and forage of molybdenum, selenium, copper, and magnesium. Imbalances of these elements in a grazing animal's diet can cause severe health problems and sometimes death.

But the Ithaca lab is not content to rest on its laurels, say Van Campen.

"For example, one of our scientists, David L. Grunes, acts as a clearinghouse for information on an animal disease called grass tetany that is seen all over the United States. Grass tetany occurs if a grazing animal doesn't have enough magnesium in its diet; it gets sick and can die.

"Dave Grunes has done a lot of research himself on this subject since 1965, but he's also made a major contribution in getting people together and in organizing workshops and symposia on this subject."

Scientists' combined efforts against grass tetany have paid off in a highly

visible way. Van Campen says, "Since 1965, there's been about an 80-percent reduction in the incidence of grass tetany through improved treatment and prevention techniques."

Animals Are What They Eat

Microbiologist James B. Russell has also focused part of his research on the animal diet.

"Cows eat grass and other forages because they can digest cellulose," says Russell. "They have bacteria in the rumen that have enzymes called cellulase, and cellulase can break down cellulose."

Since World War II, increasing levels of grain have been fed to beef and dairy cattle. The starch in grain is more digestible than cellulose, so digestion is faster and the cow can produce more meat or milk.

KEITH WELLER

Animal physiologist Willian House observes a laboratory rat fed tannins obtained from different varieties of beans. Under some conditions, tannins lower the adsorption of dietary iron and depress growth. (K-4036-1)

KEITH WELLER

These lettuce roots never touch soil or a hydroponic liquid. Instead, the plants get their nutrients from an ultrasonically produced fog. Plant geneticist Richard Zobel can simulate drought or other stresses by precisely altering the fog's volume and nutrient content. (K-4040-6)

But a problem arose with the grain-laden diet. The rumen became too acidic for the bacteria that digest cellulose.

"We wanted to know if we could perhaps use genetic engineering to construct a bacterium that would digest cellulose under acid conditions in the rumen," Russell recalls.

Experiments have shown the answer may be "yes." Initially, Russell, ARS scientist Osamu Matsushita, and David B. Wilson of Cornell University planned to insert a cellulase gene into a rumen bacteria, *Bacteroides ruminicola,* that can grow in an acid environment but was thought to produce no cellulase.

However, the researchers found *B. ruminicola* did produce a cellulase, called CMCase, that could degrade synthetic soluble cellulose but not the native insoluble cellulose in forages.

Cellulases capable of degrading insoluble cellulose must have both an "active site" and a "binding site." The CMCase from *B. ruminicola* had no binding site.

The solution seems to lie in reconstructing the CMCase gene to include a DNA segment that codes for an appropriate binding site.

More than 18 months of experiments have gone into successfully cloning the entire CMCase gene into *E. coli* bacteria, then fusing the binding site from another bacterium's cellulase gene to the CMCase gene.

"This reconstructed gene does produce a cellulase, and we're currently studying the gene's activity," Russell says. Plans are to insert the reconstructed gene back into *B. ruminicola* and return it to the rumen.

Probing Plant Preferences

For plant physiologist Leon V. Kochian, another researcher at the Ithaca lab, the hot topic is the inner workings of plants, not animals. Kochian has used microelectrode probes only 20 millionths of an inch in diameter to explore individual plant cells' preferences in nutrients.

As the tip of the probe is pushed through the outer membrane of the plant cell, the membrane closes around the probe. The probe then allows the researchers to study the cell interior to see when a particular

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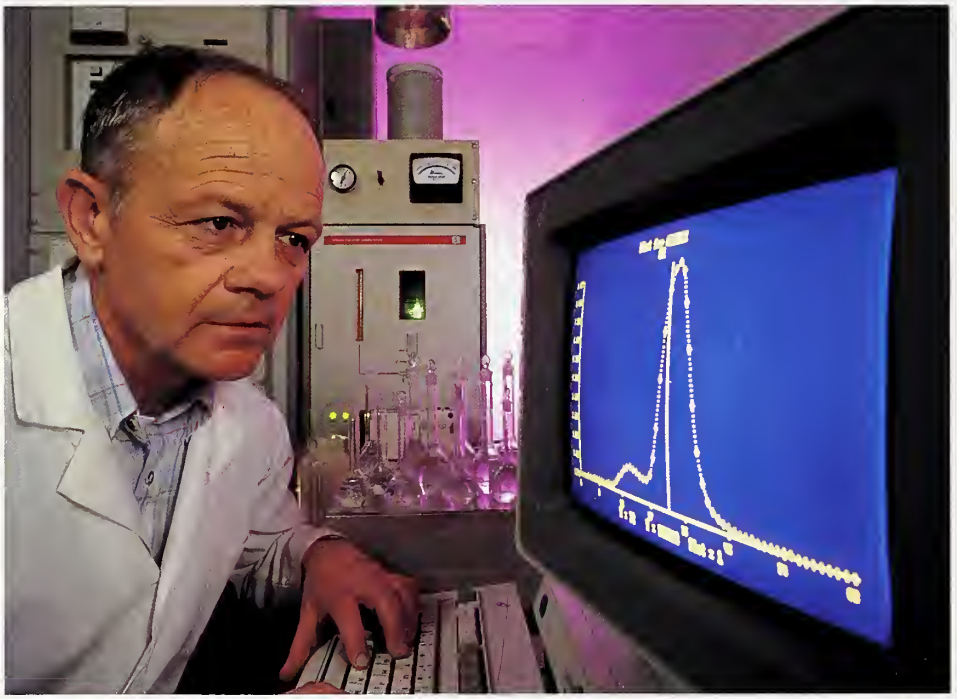


Operating at temperatures similar to the sun's surface, an inductively coupled argon plasma atomic emission spectrometer can detect and quantify 34 elements simultaneously. Chemist Earle Cary checks the computer monitor which is showing a signal for aluminum. (K-4042-2)

element, such as potassium, moves into or out of the cell.

"If we can learn more about how plant cells regulate the transport of nutrients, we might be able to manipulate the plant into absorbing more of a desirable nutrient, such as calcium," Kochian explains. "This could ultimately affect food quality."

Food quality concerns have also surfaced in Kochian's work with plant physiologist Ross M. Welch at Ithaca. The two are studying a pea plant that could someday play a key role in boosting the nutritional quality of the typical American diet.

The pea plant is a mutant that differs by only one gene from a commercial pea variety Sparkle. But the mutant, E107, behaves quite differently from Sparkle in one vital respect.

"Most plants will take up just as much iron as they need from the soil and then stop," says Welch. "But this mutant never stops taking up iron and will eventually accumulate enough to kill itself."

By studying what's happening in this self-destructive mutant, the scientists might be able to find a way to increase the amount of iron in the edible parts of crop plants. They're now trying to find out which gene is mutated and where the mutation is on that gene. Then they can study what that gene does in a normal plant.

Welch is also studying a mutant gene in corn that could affect nutritional quality of the grain. This gene, opaque-2, is responsible for making corn rich in lysine, an amino acid essential to the human diet.

"In looking at inbred corn that has opaque-2, we've found some that is 20 percent higher in iron content, and 35 percent higher in zinc, and has 25 percent more calcium, 18 percent more magnesium, and 87 percent more sulfur," Welch says.

"We know the improvements are there; now we want to know why."

Animal physiologist William A. House is tackling the equation from another direction, trying to ensure that when a nutrient such as iron is available in food, those who consume the food will derive the maximum benefit from it.

"Iron is essential so the blood can carry oxygen throughout the body," explains House. "But some Indian scientists have found that people drinking certain teas have impaired ability to absorb iron.

"The key appears to be tannins—compounds that you get from different foods. We're finding a lot of dry beans have tannins, and there's a big difference in the quantities. We've found several bean cultivars in which up to 1 percent of the bean weight is actually tannins."

House has conducted experiments in which rats were given iron that could be traced through their bodies,

KEITH WELLER

Soil scientist Wendell Norvell adjusts flow through mineral nutrients to hydroponically grown barley plants. (K-4034-2)

and then were fed diets including a half percent tannin.

In experiments involving slightly anemic rats, whose iron absorption would tend to be greater, the tannin hindered the rats' ability to absorb the iron by as much as 40 percent. In tests where nonanemic rats were used, the rats were only able to absorb about half of the iron because of the tannins' interference.

"What this tells us is that the effects of tannin on iron absorption are affected by the iron status of the animal," House concludes.

Research geneticist Richard W. Zobel's interests are more down to earth—specifically the rhizosphere, that section of earth where plant roots flourish.

"We're looking at root growth in ridge till versus conventional tillage, with manure versus commercial fertilizer, and with herbicide suppression of weeds versus suppression by cultivation," says Zobel. "Our preliminary results suggest all these techniques give different numbers of roots in corn."

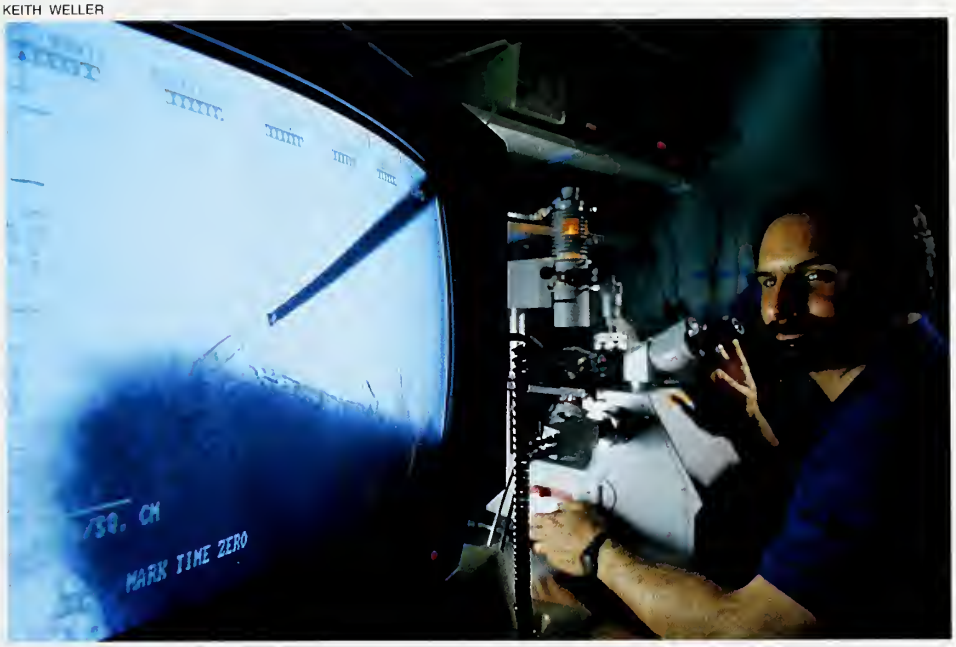
Zobel has in hand at Ithaca 11 tomato mutants whose ratio of large support roots to lateral roots he can manipulate. The laterals, called adventitious roots, "do the real exploring in the soil."

"We want to understand whether these different types of roots have different functions—whether some are more efficient at taking up nutrients, others better at taking up water, or some good at both," he says. "But already with these mutants, we're showing we can modify the plant to fit the environment."

Soil scientist Wendell A. Norvell and research chemist Earle E. Cary are also interested in the uptake of nutrients by plants, but in the controlled environment of the lab rather than the field.

In research, scientists have frequently grown plants hydroponically—with plant roots in liquid rather than in soil. This enables them to do more detailed studies of the plant's natural activities.

KEITH WELLER



Plant physiologist Leon Kochian uses a two-dimensional vibrating voltage microelectrode to map and measure tiny electric fields found around living, plant roots. (K-4046-14)

However, hydroponically grown plants have typically been grown in solutions containing nutrients at much higher levels than are normally found in soil solution (the liquid surrounding soil particles that supplies nutrients for soil-grown plants).

This difference makes it difficult to compare plants grown in nutrient solution with those grown in soil. While systems to continuously monitor and adjust nutrient levels have been developed to more closely simulate conditions in soil solution, these systems are beyond the reach of many scientists' budgets.

Norvell, Cary, and research associate Ron Checkai have created an alternative approach that is much simpler, and less expensive.

Their system circulates the solution through synthetic mineral-binding particles that hold a supply of nutrients for the growing plants. This arrangement offers the best of both worlds: nutrient-supply conditions similar to those found in soil plus the precision and control offered by hydroponics.

For all its variety, the research at the Ithaca lab maintains a constant thread that should reach easily into the next century, says Darrell Van Campen.

"Our emphasis is really trying to understand how plants take up nutrients and how they transport those nutrients to the edible portions of the plant, " he says.

"Sometimes we find something for which the practical significance isn't evident until later. But I think we have to keep our eyes open for more opportunities to apply what we know. We have to be ready to take it on to the next step."—By **Sandy Miller Hays,** ARS.

Darrell R. Van Campen, David L. Grunes, James B. Russell, Leon V. Kochian, Ross M. Welch, William A. House, James T. Madison, John F. Thompson, Earle E. Cary, Wendell A. Norvell, and Richard W. Zobel are at the U.S. Plant, Soil, and Nutrition Laboratory, Tower Road, Ithaca, NY 14853. Phone (607) 255-5480. ◆

Salad Days of a Lettuce Breeder

Plant geneticist Edward Ryder (left) and plant physiologist William Waycott, mini-lettuce creator, with other lettuce breeding lines in flower at their Salinas, California, greenhouse.

The cool, crisp salads of iceberg lettuce you may be enjoying this summer will likely be made with Salinas—America's most popular iceberg lettuce. Salinas and more than a half-dozen other varieties are the handiwork of Edward J. Ryder, one of America's foremost lettuce breeders.

At his ARS laboratory, greenhouses, and test fields in Salinas, California, Ryder has crossed promising lettuce plants to produce new iceberg-type varieties that look good, withstand the rigors of shipping, and fend off disease.

His Salinas variety reigns as a classic, setting the standard for the look and taste of a top-quality iceberg lettuce. First introduced in 1975, Salinas is now this country's most widely planted iceberg lettuce.

"Salinas is a plant breeder's dream," says Ryder. "Luck has a lot to do with its success, of course. But when a lettuce variety becomes so popular so fast, it's pretty heady stuff."

Lettuces that Ryder bred after Salinas, although perhaps lesser known, offer specialized traits prized by growers. The desert lettuce Winterset, for example, resists a devastating disease caused by lettuce mosaic virus. So does Salinas 88, which Ryder designed for cool coastal valleys. Mosaic virus gets its name from the pattern of dark and light green that appears on leaves of infected lettuce plants.

Perhaps the most appealing of the lettuces Ryder's laboratory has yielded, however, is a new mini-lettuce—a junior-size version of Salinas.

The midget lettuce is perfect for people who can't seem to use up a whole head of lettuce while it's still fresh. A single head of the new lettuce makes just enough salad for one person to eat at one sitting, Ryder says. Colleague William Waycott produced the new treat, with advice from Ryder.

The little lettuce could show up in supermarket produce sections as early as 1993, if growers and seed companies take to it. The first of these mini-icebergs will probably be a variety that is a downsized version of the familiar iceberg. But other types that look promising include a mini variety that has red-tipped leaves and another with frilly ones.

Also in the works are full-size super-lettuces that resist attack by not just one affliction, but many. Ryder envisions an iceberg-of-the-future that's impervious not only to lettuce mosaic, but also to tipburn, an unsightly browning of leaf edges; downy mildew, a white fungus of leaves; and corky root, a bacterial rot that stunts lettuce.

Meanwhile, Ryder and colleagues are tackling one lettuce affliction at a time. Horticulturist James D. McCreight has targeted the virus that causes lettuce infectious yellows, a severe disease of desert-grown lettuce.

"This is one of the toughest diseases our team has faced," says Ryder. "Some of our experimental lettuces may show less of the characteristic yellowing than others. But a truly resistant lettuce is probably years away."

Still, the time it may take to breed the improved lettuces could be cut nearly in half by Ryder's 1983 discovery of lettuces that carry the trait of early flowering. These precocious individuals produce seed about 9 to 10 weeks earlier than their counterparts.

That trait can be bred into experimental lettuces, so breeders will see the results of crosses sooner. Then, because early flowering causes havoc in commercial fields (lettuces that have sprouted a flowering stalk are bitter and unmarketable), the trait can be left out once breeders settle on the ideal parentage for a new lettuce.

Ryder credits his lifelong interest in lettuce and other leafy salad vegetables—endive, escarole, radicchio, among others—to his mother's vegetarian cooking and to happy childhood days spent tending the vegetable patch at his family's summer bungalow in upstate New York. There, and at their home in the Bronx, lettuce salads were always served at lunch and dinner. Now 61, Ryder says he's probably eaten a lettuce salad "every day of my life since I was old enough to chew."—By **Marcia Wood**, ARS.

Edward J. Ryder, James D. McCreight, and William Waycott are with the USDA-ARS Vegetable Production Research Unit, U.S. Agricultural Research Station, 1636 East Alisal St., Salinas, CA 93905. Phone (408) 755-2800. ◆

KEITH WELLER

The new iceberg mini-lettuce (left) makes just enough salad for one person to eat at one sitting. (K-3824-4)

KEITH WELLER

Expect to find ARS-developed mini-lettuce in supermarket produce sections by 1993. (K-3822-11)

Walking—Backmending Exercise for Women

MIRIAM NELSON

In studies conducted by ARS researchers at the Human Nutrition Research Center on Aging at Tufts University, volunteers walk briskly around the Boston Common.

Pat Phillipps knows Beacon Hill like the back of her hand. Hundreds of times in the course of a year she climbed the hill and walked the loop surrounding the Boston Common with 17 other women.

Phillipps was 1 of 36 women who completed a year-long study designed by physiologists at the ARS Human Nutrition Research Center on Aging at Tufts University just a few blocks away.

The researchers hoped to establish whether or not a regular routine of aerobic exercise—in this case, brisk walking four times a week—and/or a diet containing more calcium than currently recommended could help stem bone loss in women past menopause.

Numerous studies have examined how exercise, calcium, or both affect bone density in women. But the findings are inconsistent, says study leader Miriam E. Nelson, noting that earlier studies did not measure as many bone sites as this one. "We targeted the major places where osteoporosis causes breaks—the spine, hip, and wrist—plus we measured total body calcium."

According to a 1984 report by the American Academy of Orthopedic Surgeons, one-third of women over 65 will have one or more fractures of spinal vertebrae. And as women survive into their eighties, one-third will experience hip fractures. In 1987, the National Osteoporosis Foundation estimated that 1.3 million Americans 45 years and older suffer bone fractures each year costing between 7 and 10 billion dollars annually.

"Poor bone health is an increasingly common medical, social, and economic problem," says Nelson. "Its prevention or amelioration is of major importance for maintenance of health in the elderly." So Phillipps and her 17 walking partners—all of them relatively sedentary before the study—huffed and puffed around the Common and adjacent public gardens at 75 to 80 percent of their maximum aerobic capacity for about 50 minutes a day 4 days a week. Nelson served as their drill sergeant on most of the walks, making sure no one slacked off.

After a month of easing into the regimen, Phillipps says, the women wore weight belts to increase the load being carried by the skeleton. And they periodically wore heart rate monitors to ensure that heart rates stayed up to speed. "As you get more fit, your pulse gets slower and you have to walk faster to keep it up," she notes.

Meanwhile, 18 other women of similar age—the average was 60—and fitness level maintained their sedentary lifestyles for comparison.

Half of the women in each group consumed a milkshake-like drink containing an extra 800 milligrams of calcium over and above the 800 mg they were already consuming in their normal diet. The other half got a shake containing only a trace of calcium so researchers could check

the effects of extra calcium with and without exercise.

Both the walking and the extra calcium paid off, but in different bones, says Nelson. While the sedentary women lost an average 7 percent of spine bone during the year, the walkers increased spine bone by a slight 0.5 percent. The changes were in the spongy bone, or trabecular bone, which constitutes the center of the vertebra. Sixty percent of the vertebral bone is trabecular. There did not seem to be any change in the denser cortical bone covering each vertebra, Nelson says.

That's important news, according to William J. Evans, who heads physiology research at the Boston center. "Once you lose trabecular bone, it doesn't appear you can gain it back to any significant extent. So the strategy has to be to try to arrest the loss."

Getting extra calcium, on the other hand, increased the bone density of the hip, says Nelson. And its effect in the nonwalkers was the same as in the walkers. The improved bone health was probably in both trabecular and cortical bone; the researchers did not measure the two types independently.

Regardless of activity level, says Nelson, the women who got the high calcium drink gained an average 2 percent in bone density at the hip, while those who got the placebo shake lost 1.1 percent.

The bone under study was not part of the pelvic girdle but rather the neck of the thigh bone (femur) which fits up into the hip socket. "A very high percentage of breakages occur here," Nelson explains. Nelson concludes that "exercise and extra calcium appear to have different effects at varying sites of the skeleton." So it looks like women need to walk and drink calcium at the same time to get the total benefit. "It really should be a lifelong change in diet and exercise," says Nelson, not a stopgap measure after menopause.

The fact that exercise appears to have a greater effect on spine trabecular bone than calcium has on hip cortical bone has a logical explanation, says Evans. All bone is continually being broken down and replaced throughout life. "But trabecular bone turns over six to seven times faster than cortical bone, so you're likely to see an effect faster."

The fact that extra calcium didn't enhance the effects of exercise, however, was somewhat of a surprise. "We thought there might be a synergistic effect," says Evans, because some reports had speculated postmenopausal women need about 1,200 mg/day to replenish calcium losses.

Nelson points out that the calcium for this study was "au naturel," unlike other studies that used calcium supplements. The 16-ounce shake contained enough milk and milk powder to provide an extra 800 mg. A very low calcium lookalike, tastealike placebo drink was developed for the other women.

There were a few women in the high-calcium shake group who had problems digesting the lactose contained in the drink. These few women simply split up the 16-ounce milk shake into four servings throughout the day—"and they tolerated the lactose very well," she says.

Neither the extra calcium nor the walking had any effect on the wrist bone—which is mostly cortical bone—or on the total body calcium level, Nelson says.

Her findings were published in the May issue of American Journal of Clinical Nutrition.

But brisk walking provided a side benefit. The walkers improved their aerobic capacity—also known as VO_2 max—an average 8.8 percent over the course of the study while the sitters lost 7.5 percent.

After a couple of months on the Beacon Hill circuit, "when I got used to walking, I noticed a great change," says Phillipps. "You'd think it would tire you out, but it didn't. It had the opposite effect—I felt invigorated. I also ate a smaller lunch. Walking abated my appetite a little."—By **Judy McBride**, ARS.

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Babesiosis Test Is on the Fast Track

Horses around the world—from the polo ponies of Argentina to Russian thoroughbreds—may carry a serious parasitic blood disease called equine babesiosis.

In countries where the disease is endemic, such as Brazil, Argentina, Russia, and Poland, many horses maintain low, persistent levels of infection and are thereby immune to a severe illness.

Infection can be fatal, however, in animals not previously exposed to the parasite, including most American horses, says Donald P. Knowles, of the ARS Animal Disease Research Unit in Pullman, Washington.

More safety for U.S. horses may be on the way, though. A new discovery by Knowles will aid veterinarians in detecting babesiosis more accurately and help check this sometimes deadly disease.

USDA's Animal and Plant Health Inspection Service restricts horses that test positive for babesiosis from entering the United States.

But the current testing method occasionally yields an uncertain result, which led officials to seek an improved test, according to Al Strating, director of science and technology at APHIS. The agency funded the work done by Knowles and his colleagues at Washington State University.

Babesiosis resembles malaria in humans because in both diseases, insects transmit the infectious agent, which attacks and destroys red blood cells. Sick animals become feverish and lethargic and refuse to eat.

Microscopic, single-celled parasites, called *Babesia equii,* enter the horse through infected, blood-sucking ticks. The parasites then multiply in the bloodstream, forming tiny pear- or ring-shaped bodies, called merozoites, that invade the red cells.

Next, the horses' immune system kicks in and forms antibodies against the merozoites in an attempt to fend off the assault.

By studying the blood of infected horses, Knowles identified specific proteins found on the surface of the merozoites. Certain proteins, he found, were the same, regardless of where the horse originated. This information is important in devising an antibody-based test that would work anywhere in the world.

"One merozoite protein produced an antibody response in nearly 200 horses from 20 different countries," says Knowles.

JOHN KUCHARSKI

Most American horses can become targets of equine babesiosis, a blood disease caused by the parasite *Babesia equii.* (K-4032-1)

His colleague, Lance E. Perryman, of Washington State University, made a monoclonal antibody that can accurately detect this protein. The antibodies are produced by a laboratory cell culture of fused mouse spleen and myeloma cells called a hybridoma. These antibodies are being studied as a component of a diagnostic test.

Several companies have expressed interest in the test, says Knowles. APHIS' National Veterinary Services Laboratory in Ames, Iowa, which screens all blood samples from imported animals, would be the main users of the test, he adds.

The NVSL often runs a courtesy test, which allows importers to have an animal's antibody level checked before it's shipped, says Wayne M. Frerichs, chief of diagnostics at the bacteriology lab at NVSL.

Horses are then re-tested when they actually arrive at one of the quarantine facilities in the United States, in Miami, New York, Los Angeles, and Honolulu. Last year, over 45,000 horses were tested for babesiosis. Only 2 or 3 percent were denied entry because of a positive test, according to Frerichs.

A very small number of tests give inconclusive results and must be repeated, using a more expensive, more time-consuming test.

The monoclonal antibody test may eliminate those problems, says Knowles.

Because previously exposed horses exhibit a strong antibody response to the protein, Knowles says it may also be a good candidate for producing a vaccine against the disease.

He is currently using recombinant DNA techniques to produce enough of the protein to use in vaccine trials, which may begin this summer.

Race horses make up the bulk of the international horse commerce. Horse fanciers also want to import exotic horses, such as the German Trichanor, for breeding purposes. Other foreign breeds have desirable qualities for varied uses, from barrel racing and trail riding to draft work.

Horses may also travel for international competition, as in polo games or equestrian competition. About 350 horses came to Los Angeles, for example, to compete in the 1984 Games.—By **Julie Corliss,** ARS.

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Now It's Sugar, Now It's Alternan

The beet and cane sugar processing companies may someday harness the power of a microbe to convert their products into nonfattening food ingredients, including a substitute for gum arabic.

"We think enzymes produced by some strains of the bacterium *Leuconostoc mesenteroides* could transform sugar into less expensive substitutes for gum arabic and other noncaloric food components," says ARS chemist Gregory L. Cote. He sees this process as creating an additional market for U.S. beet and cane sugar while cutting dependence on imported products.

Small amounts of gum arabic are widely used by food processors to help icings stick to cake, prevent syrups from crystallizing, and maintain a foamy head on a glass of beer—all without changing flavor. Some of the commodity goes into industrial products such as ink and adhesives.

Presently, the United States buys about 25 million pounds of gum arabic annually from the Sudan and other countries at costs ranging from $1 to $3 per pound.

In his studies at the ARS National Center for Agricultural Utilization Research, Peoria, Illinois, Cote isolated an enzyme from *L. mesenteroides* that in its purified form converts sugar to alternan, a carbohydrate polymer. Alternan, in one of its forms, is similar to gum arabic. The major byproduct of alternan synthesis is fructose.

As different strains of *L. mesenteroides* are discovered or genetically engineered to become more efficient, Cote envisions applications for alternan and other dextrans will expand.

He has already found one strain that produces dextrans with a chemical structure that resists breakdown by enzymes such as the amylases. Other strains he worked with produce dextrans that are more resistant to breakdown by heat and that are less viscous than dextrans now in commerce.

Pursuing improved alternan synthesis, Cote and his colleagues are screening a collection of bacteria for strains that make the enzyme in a pure enough form that they won't have to separate it from other enzymes. The researchers also hope to clone the gene responsible for producing alternan and to genetically engineer a microorganism to produce high yields of the enzyme.—By **Ben Hardin,** ARS.

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MICHAEL LICHTER

Wheat (K-3597-18)

Wheat Hardness: High-Precision Knife Tells All

Razor-thin slivers of a wheat kernel, sliced by an automated, high-precision knife, may reveal whether a promising new wheat is best classified as hard or soft. The designation dictates wheat's eventual use and often the price it commands, says ARS plant physiologist Gregory M. Glenn.

Hard wheats tend to be best for breadmaking, while soft varieties make the best flours for cakes, crackers, and cookies.

Breeding sometimes blurs the line between hard and soft, however. The distinction may be hard to make, for example, when America's most widely grown wheats—hard red winter and soft red winter—are crossed.

Wheat breeders who can buy or borrow an automated knife or microtome—a standard instrument at many major research centers—will find Glenn's method reliable and easy to use. What's more, breeders can use the unsliced portion of the kernel to grow a new plant that produces a fresh supply of seeds. The slicing test requires only about a third of the kernel and doesn't affect the germ, essential for planting. That's a boon to breeders who need every available kernel of a new, experimental wheat.

At his laboratory in Albany, California, Glenn has tested the classification technique on 60 commercial wheat varieties, using kernels provided by ARS wheat quality laboratories in Ohio, Kansas, North Dakota, and Washington. His preliminary results compare favorably with those from other, better known tactics for judging hardness.

Each kernel is first placed in a tiny holder in the microtome. The device cuts several slices, each about 2 micrometers thick, or some 30 times finer than a human hair.

A microscope connected to the microtome gives a clear view of the kernel and slices. Those shaved from hard wheat are sturdy, pliable, intact disks. Slices of a soft wheat, however, crumble readily into a tiny pile of soft powder.

Glenn is seeking a patent for the approach, which he discovered by accident while cutting kernels for another project.—By **Marcia Wood,** ARS.

For further information on Patent Application No. 07/536,865, "Method for Classifying Wheat Kernels as Hard or Soft," contact Gregory M. Glenn, USDA-ARS Western Regional Research Center, Food Quality Research Unit, 800 Buchanan St., Albany, CA 94710. Phone (415) 559-5677. ◆

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